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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Noboru Ichinose, et al.

Serial No.: 10/567,369 **Group Art Unit:** 2814

Filed: May 15, 2006 **Examiner:** Sarah Kate Salerno

For: SEMICONDUCTOR LAYER WITH A GA_2O_3 SYSTEM

Honorable Commissioner of Patents
Alexandria, Virginia 22313-1450

SUBMISSION OF VERIFIED ENGLISH TRANSLATION OF THE PRIORITY DOCUMENT

Sir:

Submitted herewith is a verified English translation of the Specification, Claims, Abstract, and Drawings and translator's verification that the English translation is a true English translation of the Japanese Application Number 2003-290862 filed August 8, 2003, upon which application the claim for priority is based.

Approval and acknowledgment of receipt are respectfully requested.

Respectfully submitted,

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VERIFICATION OF TRANSLATION

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Sanban-cho, Chiyoda-ku, Tokyo, Japan declare as follows:

1. That I am well acquainted with both the English and Japanese languages, and

2. That the attached document is a true and correct translation made by me to the best of my knowledge and belief of:-

The specification accompanying the Application No. 2003-290862 for a Patent made in Japan filed on August 8, 2003.

September 27, 2010

Kenji TSUNODA

(No witness required)

JAPAN PATENT OFFICE

This is to certify that the annexed is a true copy of the following application as filed with this Office.

Date of Application:	August 8, 2003
Application Number:	Patent Application No. 2003-290862
[ST. 10/C]:	[JP2003-290862]
Applicant(s):	KOHA CO., LTD.

November 25, 2004

Commissioner,

Japan Patent Office Hiroshi OGAWA

[DOCUMENT] APPLICATION FOR PATENT
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[FEE INDICATION]
[PREPAID DOCKET NUMBER] 038070
[OFFICIAL FEE] 21000
[LIST OF ATTACHED DOCUMENT]
[ITEM] SCOPE OF CLAIM FOR PATENT 1
[ITEM] SPECIFICATION 1
[ITEM] DRAWINGS 1
[ITEM] ABSTRACT 1
[NUMBER OF GENERAL POWER OF ATTORNEY] 9504127

[Document] Scope of Claim for Patent

[Claims]

[Claim 1]

A semiconductor layer, characterized by comprising:

a first layer made of a Ga_2O_3 system semiconductor; and

a second layer obtained by replacing a part or all of oxygen atoms of the first layer with nitrogen atoms.

[Claim 2]

A semiconductor layer according to claim 1, characterized in that:

the second layer is made of a GaN system compound semiconductor.

[Claim 3]

A semiconductor layer according to claim 1, characterized in that:

the first layer is a Ga_2O_3 system single crystal substrate.

[Claim 4]

A semiconductor layer according to claim 1, characterized in that:

the first layer is made of Ga_2O_3, $(In_xGa_{1-x})_2O_3$, $(Al_xGa_{1-x})_2O_3$, $(In_xAl_yGa_{1-x-y})_2O_3$, or the like, as a main constituent.

[Claim 5]

A semiconductor layer according to claim 2, characterized in that:

the second layer is made of GaN, $In_zGa_{1-z}N$, $Al_zGa_{1-z}N$, $In_zAl_pGa_{1-z-p}N$, or the like, as a main constituent.

[Claim 6]

A semiconductor layer, characterized by comprising:

a first layer made of a Ga_2O_3 system semiconductor;

a second layer made of a GaN system compound semiconductor and obtained by replacing a part or all of oxygen atoms of the first layer with nitrogen at-

oms; and

a third layer made of an GaN system epitaxial layer and formed on the second layer.

[Claim 7]

A semiconductor layer, characterized by comprising:

a first layer made of a Ga_2O_3 system semiconductor; and

a second layer made of a GaN system compound semiconductor and formed on the first layer.

[Claim 8]

A semiconductor layer, characterized by comprising:

a first layer made of a Ga_2O_3 system semiconductor;

a second layer made of a GaN system compound semiconductor and formed on the first layer; and

a third layer made of an GaN system epitaxial layer and formed on the second layer.

[Document] Specification

[Title of the Invention] SEMICONDUCTOR LAYER

[Technical Field]

[0001]

The present invention relates to a semiconductor layer, and more particularly to a semiconductor layer in which a GaN system epitaxial layer having high crystal quality can be obtained.

[Background Art]

[0002]

FIG. 3 shows a conventional semiconductor layer. This semiconductor layer includes an Al_2O_3 substrate 11 made of Al_2O_3, an AlN layer 12 which is formed on a surface of the Al_2O_3 substrate 11, and a GaN growth layer 13 which is formed on the AlN layer 12 through epitaxial growth by utilizing an MOCVD (Metal Organic Chemical Vapor Deposition) method (refer to Patent document 1 for example).

[0003]

According to this semiconductor layer, the AlN layer 12 is formed between the Al_2O_3 substrate 11 and the GaN growth layer 13, whereby mismatch in lattice constants can be reduced to reduce imperfect crystalline.

[Patent document 1] JP 52-36117 B

[Disclosure of Invention]

[Problem to be solved by the Invention]

[0004]

However, according to the conventional semiconductor layer, the lattice constants of the AlN layer 12 and the GaN growth layer 13 cannot be perfectly made match each other, and thus it is difficult to further enhance crystal quality of the GaN

growth layer 13. In addition, when the conventional semiconductor layer is applied to a light emitting element, crystalline of a luminous layer is degraded, and luminous efficiency is reduced.

[0005]

Therefore, an object of the present invention is to provide a semiconductor layer in which a GaN system epitaxial layer having high crystal quality can be obtained.

[Means for solving the problems]

[0006]

In order to attain the above-mentioned object, the present invention provides a semiconductor layer characterized by including a first layer made of a Ga_2O_3 system semiconductor, and a second layer obtained by replacing a part or all of oxygen atoms of the first layer with nitrogen atoms.

[Effect of the invention]

[0007]

According to the semiconductor layer of the present invention, the second layer which is obtained by replacing a part or all of the oxygen atoms of the first layer with the nitrogen atoms is formed on the first layer made of the β-Ga_2O_3 system semiconductor, whereby the second layer which is made of the GaN system compound semiconductor and which has the high crystalline is obtained without interposing a buffer layer. Hence, when the GaN system epitaxial layer is formed on the second layer, the lattice constants of the second layer and the GaN system epitaxial layer can be made match each other, or can be made exceedingly approximate to each other, and thus the GaN system epitaxial layer having the high crystal quality is obtained.

[Best Mode for Carrying Out the Invention]

[0008]

A semiconductor layer according to an embodiment mode of the present invention will be described. This embodiment mode is constituted by a first layer which is made of a Ga_2O_3 system semiconductor, a second layer which is made of a GaN system compound semiconductor and which is obtained on the first layer by subjecting a surface of the first layer to nitriding processing or the like to replace a part or all of oxygen atoms of the first layer with nitrogen atoms, and a third layer which is made of a GaN system epitaxial layer on the second layer. Here, "the Ga_2O_3 system semiconductor" contains semiconductors such as Ga_2O_3, $(In_xGa_{1-x})_2O_3$, $(Al_xGa_{1-x})_2O_3$, and $(In_xAl_yGa_{1-x-y})_2O_3$, or the like, and also contains semiconductors each showing an n-type conductive property or a p-type conductive property through atom replacement or atom defects made for such a semiconductor. In addition, "the GaN system compound semiconductor" and "the GaN system epitaxial layer" contain semiconductors such as GaN, $In_zGa_{1-z}N$, $Al_zGa_{1-z}N$, and $In_zAl_pGa_{1-z-p}N$, or the like, and also contain semiconductors each showing an n-type conductive property or a p-type conductive property through atom replacement or atom defects made for such a semiconductor.

[0009]

For example, as a first example, the second layer and the third layer can be made of the same compound semiconductor as in the first layer made of Ga_2O_3, the second layer made of GaN, and the third layer made of GaN. In addition, as a second example, the second layer and the third layer can also be made of different compound semiconductors, respectively, as in the first layer made of made of Ga_2O_3, the second layer made of GaN, and the third layer made of $In_zGa_{1-z}N$. Also, as a third example, the second layer and the third layer can also be made of different compound semiconductors, respectively, and the first layer and the second layer

can also be made in accordance with a combination different from that in the first example and the second example as in the first layer made of $(In_xGa_{1-x})_2O_3$, the second layer made of $In_zAl_pGa_{1-z-p}N$, and the third layer made of $Al_zGa_{1-z}N$.

[0010]

According to the embodiment mode, since the lattice constants of the second layer and the third layer can be made match each other, or can be made exceedingly approximate to each other, the GaN system epitaxial layer having high crystal quality is obtained.

[Embodiment 1]

[0011]

FIG. 1 shows a semiconductor layer according to Embodiment 1 of the present invention. The semiconductor layer of Embodiment 1 includes a β-Ga_2O_3 substrate 1, as a first layer, which is made of a β-Ga_2O_3 single crystal, a GaN layer 2 with about 2 nm thickness, as a second layer, which is formed by subjecting a surface of the β-Ga_2O_3 substrate 1 to nitriding processing, and a GaN growth layer 3, as a third layer, which is formed on the GaN layer 2 through epitaxial growth by utilizing an MOCVD method for example. Oxygen atoms of the β-Ga_2O_3 substrate 1 are replaced with nitrogen atoms in the nitriding processing, thereby forming the GaN layer 2.

[0012]

FIG. 2 shows processes for manufacturing the semiconductor layer. Firstly, the β-Ga_2O_3 substrate 1 is manufactured by utilizing an FZ (floating zone) method (process a). In the first place, a β-Ga_2O_3 seed crystal and a β-Ga_2O_3 polycrystalline raw material are prepared.

[0013]

The β-Ga_2O_3 seed crystal is obtained by cutting down a β-Ga_2O_3 single

crystal through utilization or the like of a cleaved face and has a prismatic shape having a square in cross section, and its axis direction matches a-axis <100> orientation, b-axis <010> orientation, or c-axis <001> orientation.

[0014]

For example, powders of Ga_2O_3 with a purity of 4N are filled in a rubber tube, subjected to cold compression at 500 MPa, and sintered at 1500°C for 10 hours, thereby obtaining the β-Ga_2O_3 polycrystalline raw material.

[0015]

Next, heads of the β-Ga_2O_3 seed crystal and the β-Ga_2O_3 polycrystalline are made contact each other in ambient of mixed gas of nitrogen and oxygen (changing from 100% nitrogen to 100% oxygen) at a total pressure of 1 to 2 atmospheres in a silica tube, contact portions thereof are heated to be molten, and the dissolved matter of the β-Ga_2O_3 polycrystalline is cooled, thereby producing the β-Ga_2O_3 single crystal. When being grown as a crystal in the b-axis <010> orientation, the β-Ga_2O_3 single crystal has strong cleavage in a (100) face, and hence the β-Ga_2O_3 single crystal is cut along a face vertical to a face parallel to the (100) face, thereby manufacturing the β-Ga_2O_3 substrate 1. Incidentally, when being grown as a crystal in the a-axis <100> orientation or c-axis <001> orientation, the β-Ga_2O_3 single crystal has weak cleavage in the (100) face and a (001) face. Hence, the processability for all the faces becomes excellent, and thus there is no limit to the cut face as described above.

[0016]

Next, the β-Ga_2O_3 substrate 1 is etched by being boiled in a nitric acid solution at 60°C (process b). The resulting β-Ga_2O_3 substrate 1 is then immersed in ethanol and subjected to ultrasonic cleaning (process c). Moreover, after being immersed in water and subjected to the ultrasonic cleaning (process d), the β-Ga_2O_3

substrate 1 is dried (process e) and subjected to vacuum cleaning at 1000°C in a growth chamber of an MOCVD system (process f) to clean a surface of the β-Ga_2O_3 substrate 1.

[0017]

Next, the β-Ga_2O_3 substrate 1 is subjected to nitriding processing (process g). That is to say, the β-Ga_2O_3 substrate 1 is heated for a predetermined period of time in a predetermined ambient atmosphere in the growth chamber of the MOCVD system. The ambient atmosphere (including the atmosphere), the heating temperature, and the heating period of time are suitably selected, whereby the desired GaN layer 2 is obtained on the surface of the β-Ga_2O_3 substrate 1. For example, the β-Ga_2O_3 substrate 1 is heated at 1050°C for 5 minutes in NH_3 ambient at 300 torr, whereby the thin GaN layer 2 with about 2 nm thickness is formed on the surface of the β-Ga_2O_3 substrate 1.

[0018]

Next, GaN is grown by utilizing the MOCVD method to obtain the GaN growth layer 3 (process h). That is to say, when a pressure in the growth chamber of the MOCVD system is reduced to 100 torr, and ammonia gas and trimethylgallium (TMG) are supplied as an N supply raw material and a Ga supply raw material to the growth chamber, respectively, the GaN growth layer 3 with about 100 nm thickness for example grows on the GaN layer 2. The thickness of the GaN growth layer can be controlled by adjusting a concentration of the supply raw materials, the heating temperature, and the like.

[0019]

In Embodiment 1, when trimethylaluminum (TMA) is supplied together with TMG, an AlGaN layer can be formed as the second layer instead of the GaN layer 2. In addition, when trimethylindium (TMI) is supplied together with TMG, an InGaN

layer can be formed as the second layer instead of the GaN layer 2.

[0020]

According to Embodiment 1, the following effects are obtained.

(1) Since the β-Ga_2O_3 substrate 1 having the high crystalline is obtained, the GaN layer 2 formed thereon is obtained which is low in through dislocation density and which is high in crystalline. Moreover, since the GaN layer 2 and GaN growth layer 3 match in lattice constants each other, and also the GaN growth layer 3 grows so as to succeed to the high crystalline of the GaN layer 2, the GaN growth layer 3 is obtained which is less in through dislocation and which is high in crystalline.

(2) A p-n junction is formed between the n-type GaN growth layer and the p-type GaN growth layer such that a light emitting element such as a light emitting diode or a semiconductor laser with the p-n junction can be manufactured.

(3) Since a luminous layer having high crystalline is obtained when the present invention is applied to the light emitting element, luminous efficiency is enhanced.

(4) Since the β-Ga_2O_3 substrate 1 has the conductive property, when the light emitting element is manufactured, it is possible to adopt a vertical type structure in which electrodes are taken out from a vertical direction of a layer structure and thus it is possible to simplify the layer structure and the manufacture process.

(5) Since the β-Ga_2O_3 substrate 1 has a translucent property, light can also be taken out from the substrate side.

(6) Since the vacuum cleaning (process f), the nitriding processing (process g), and the GaN epitaxial growth (process d) are continuously performed within the growth chamber of the MOCVD system, the semiconductor layer can be efficiently produced.

[0021]

At that, InGaN, AlGaN or InGaAlN may also be grown instead of the GaN growth layer 3. In the case of InGaN and AlGaN, the lattice constants thereof can be made nealy match those of the GaN layer 2. In the case of InAlGaN, the lattice constants thereof can be made match those of the GaN layer 2.

[0022]

For example, when an Si-doped GaN layer is formed on the thin film GaN layer 2, a non-doped InGaN layer is formed on the Si-doped GaN layer, and an Mg-doped GaN layer or AlGaN layer is formed on the non-doped InGaN layer, a double hetero type light emitting element is obtained. At this time, when a well layer and a barrier layer which are different in In composition ratio from each other are alternately formed for formation of the non-doped InGaN layer, a laser diode element having an MQW (multi-quantum well layer) is obtained.

[0023]

On the other hand, when in FIG. 1, the GaN layer 2 and the substrate 1 are removed after the GaN growth layer 3 with a predetermined thickness grows, the GaN substrate is obtained. Likewise, an InGaN layer, an AlGaN layer or an InGaAlN layer is formed instead of the GaN growth layer 3, whereby respective substrates can be obtained.

[0024]

In addition, while the FZ method has been described as the growing method for the β-Ga_2O_3 substrate 1, any other suitable growth method such as an EFG (Edge-defined Film-fed Growth method) method may also be adopted. Also, while the MOCVD method has been described as the growing method for the GaN system epitaxial layer, any other suitable growth method such as a PLD (Pulsed Laser Deposition) method may also be adopted.

[0025]

In addition, the semiconductor layer of the present invention is not limited to the light emitting element, and thus can be applied to various kinds of semiconductor components or parts.

[Brief Description of the Drawings]

[0026]

[FIG.1] FIG. 1 is a cross sectional view of a semiconductor layer according to Embodiment 1 of the present invention.

[FIG.2] FIG. 2 is a flow chart showing processes for manufacturing the semiconductor layer according to Embodiment 1 of the present invention.

[FIG.3] FIG. 3 is a cross sectional view of a conventional semiconductor layer.

[Reference Numerals]

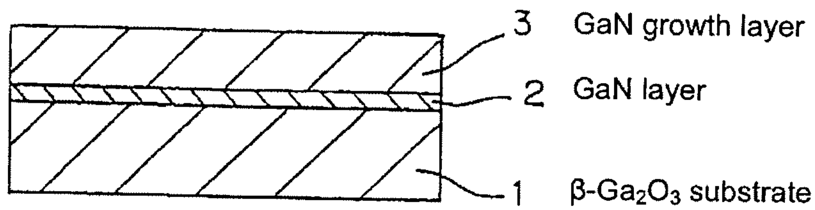
[0027]

1	β-Ga_2O_3 substrate
2	GaN layer
3	GaN growth layer
11	Al_2O_3 substrate
12	AlN layer
13	GaN growth layer

[Document] Drawings

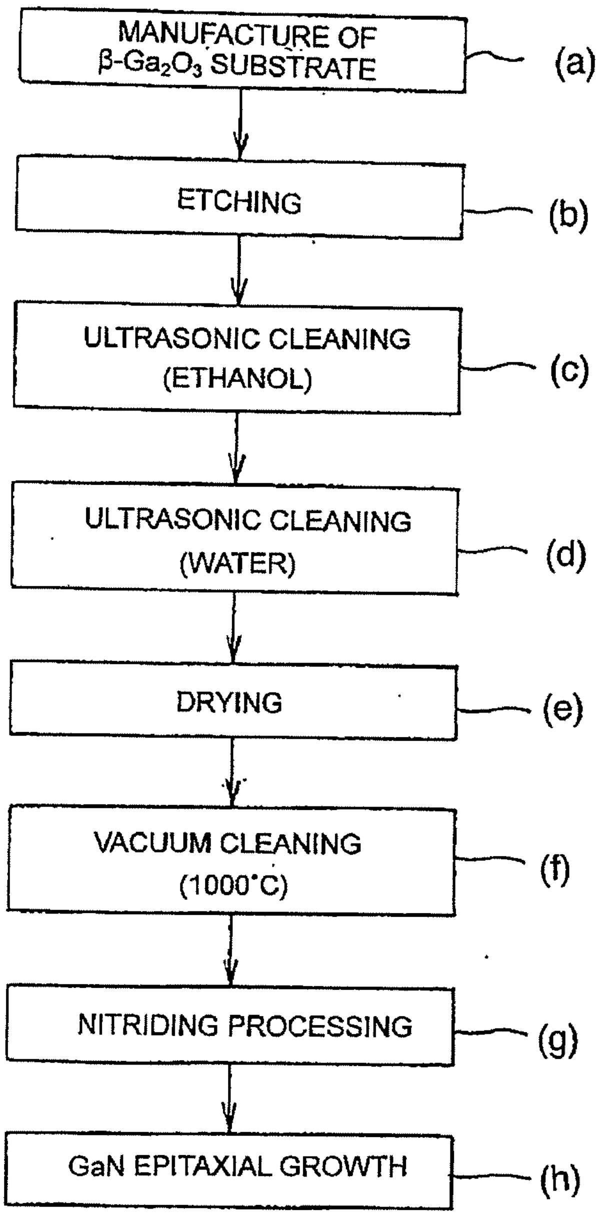
[FIG.1]

FIG. 1



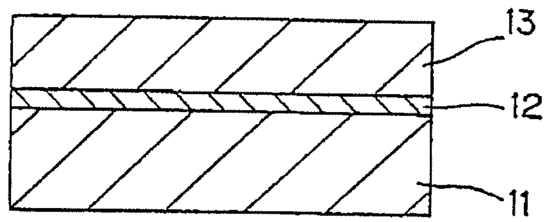
[FIG.2]

FIG. 2


MANUFACTURE OF β-Ga_2O_3 SUBSTRATE
(a)
ETCHING
(b)
ULTRASONIC CLEANING (ETHANOL)
(c)
ULTRASONIC CLEANING (WATER)
(d)
DRYING
(e)
VACUUM CLEANING (1000°C)
(f)
NITRIDING PROCESSING
(g)
GaN EPITAXIAL GROWTH
(h)

[FIG.3]

FIG. 3



[Document] Abstract

[Summary]

[Object] To provide a semiconductor layer in which a GaN system epitaxial layer having high crystal quality can be obtained.

[Means for solving the problems]

The semiconductor layer includes a β-Ga_2O_3 substrate 1 made of a β-Ga_2O_3 single crystal, a GaN layer 2 formed by subjecting a surface of the β-Ga_2O_3 substrate 1 to nitriding processing, and a GaN growth layer 3 formed on the GaN layer 2 through epitaxial growth by utilizing an MOCVD method. Since lattice constants of the GaN layer 2 and the GaN growth layer 3 match each other, and the GaN growth layer 3 grows so as to succeed to high crystalline of the GaN layer 2, the GaN growth layer 3 having high crystalline is obtained.

[Selected figure] FIG.1